IRRIGATION SYSTEMS IN VIJAYNAGAR EMPIRE TIMES AND IRRIGATION STRUCTURES IN THE OLD MYSORE STATE

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ABSTRACT

India and Iran have common bondage from times immemorial as irrigation systems in both the countries are age old. The Persian wheel to lift water is a technique that came to India from Iran during Mogul times. Like wise the Ghanat system of tapping water from the hill slope by underground tunnels is also a technique from Iran used in many places in India during the Mogul time. Both are in existence in various parts of India. The irrigation systems during Vijaynagar Empire in the 14^{th} century in the form of tank systems as well as simple diversion structures across large rivers like Tungabhadra are working efficiently even today although their maintenance is being done poorly. The gauging devices to measure tank storage and apportioning for various purposes speak of the high degree of understanding of Hydraulics and Hydrology of the then engineers specializing in water management and who were named as Jalatantris. There are even today in existence treatises on water management in some of the old archives in the country. Like wise the Wadeyars who ruled the princely state of Mysore during the 15^{th} century onwards built number of irrigation diversion works across Cauvery River in the South India and many structures are in existence even today working well. The Bangara Doddi Kaluve Aqueduct carrying a distributary across the river Cauvery is more than 4 centuries old in good working condition and probably the oldest aqueduct in service in the world. The paper describes the design and construction features of the irrigation systems of the Vijaynagar Empire as well as those of the Princely Mysore State with some detail along with lessons that could be learnt from these historical and physical evidences in the field of water resources engineering with illustrations. Along with these two instances from the history of irrigation development in India are two cases that taught the engineers of the world about the need for providing a surplusing arrangements during flood periods and the understanding of flood hydrology and also the instance of a dam built in the beginning of the 20^{th} century that made the water resource engineers aware of the fact of uplift pressure in the base of solid gravity dams, leading to such new interventions as the inspection and drainage gallery to relive the uplift pressure which is a common feature in all the modern masonry and concrete dams in the world. This led to a more safer technique in the design of gravity structures on

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rock foundations and is now a standard in all text books of dam engineering taught in the field of civil engineering.

Note: numerals in brackets ( ) in the text refer to the serial number of the illustration in the list of illustrations given at the end of the text as annexure. The text should be read with the corresponding illustration

1. INTRODUCTION

1.1. Historically, there has been a close bond between India and Iran from times immemorial in various fields such as culture, tradition, religion, and philosophy and even in the irrigation development. The Persian wheel to lift water from wells is a technique that came to India from Iran when the Moguls set foot in search of wealth centuries ago. This device was an improvement over the indigenous contraption of using a number of earthen pots strung on a rope chain attached to a rotating wheel over a well and actuated by a pair of bullocks moving in a circle on the adjoining ground with a central pivot and a crude gear mechanism to turn the rotating wheel over the well to lift the water (2). The Persian wheel became popular all over the Gangetic plains and the technique also moved to South India. Likewise the Ghanat system of collecting water from the hillsides through horizontal boring is also one other technique that was adopted in India.

1.2. Harnessing water from rivers is a technique developed in India thousands of years ago as is witnessed by the Grand Anicut (3) in South India across the river Cauvery that is highly exploited for irrigation purposes. Such and other techniques have also been taken in by Iran and other countries. Thus historically there has been a cross fertilization of ideas and techniques for the mutual benefit of the two countries.

1.3. This paper deals briefly some of the important irrigation developments in India and in particular elaborates the irrigation systems of the Vijaynagar Empire that flourished in the 14^{th} and 16^{th} centuries with a high degree of water management both for domestic and irrigational purposes. Although the domestic supply of water as done in that period is not in existence except the ruins of the water channels, (4,5,6&7) the irrigation supply for agriculture is continuing to function albeit with modification from time to time even now. The paper also covers some of the irrigation systems developed in the erstwhile Mysore state now merged in the larger Karnataka state during the 17^{th} and 18^{th} centuries by the past rulers for the benefit of their subjects harnessing the Cauvery River which flows through Karnataka. Two historical features in the country are also included as a tail piece.

2. IRRIGATION DEVELOPMENT UNDER THE VIJAYNAGAR EMPIRE

2.1. Before the advance of the Muslims under the mogul rule in the country towards South, there existed a powerful empire ruling most of the South India conquering a number of smaller kingdoms. This empire is famously known with its capital at Hampi earlier known as Vijaynagara (8) on the banks of the river Tungabhadra. It was at its peak under the rule of Krishna Devaraya the most powerful and popular king of the dynasty, which controlled South India for nearly two centuries spanning between the

14th and 16th centuries. Under the rule of Krishna Devaraya, several diversion works across the river Tungabhadra were constructed with a number of irrigation channels for extensive irrigation for agriculture and also for domestic water supply to the capital with its number of dwellings and the palaces of the kings. The domestic supply was mostly for the royal centre of the palace consisting of various bath structures and temple tanks. (9) of the palace. These are now in ruins following the end of the Empire that was conquered by the Muslim rulers of the Bahamani kingdom of Bijapur after the defeat of the later Vijaynagar kings in the battle of Talikote in the year 1565.

2.2. However the irrigation systems were not so much damaged by the Muslim conquerors and continue to supply water to agriculture fields even to this day, with some changes from time to time. The important channels that are functioning are the Raya and the Basavanna canals supplying water for irrigation in the agricultural zone between Hospet and Kamlapuram close to the Tungabhadra River (10). The canals were constructed during the medieval period. They have been subjected to a number of major changes during the 19th and 20th centuries. Currently the modern Tungabhadra dam at Mamalapuram supplies the canals as the original diversion structures are submerged by the Tungabhadra reservoir (11). The low level canal of the Tungabhadra dam incorporates the old Raya canal. The Basavanna canal (12) had originally irrigated a large tract of agricultural land between Vallabhi puram and Amaravtai.

2.3. The Tungabhadra dam has drowned most of the old canals, which were later extended to irrigate the land between Hospet and Kamlapuram while a portion of the canal is remodeled to carry the Tungabhadra waters. The Raya and Basavanna canals are presently combined into a single supply channel called the R&B canal which takes off from (11) the dam between the Tungabhadra right bank canal and the Tungabhadra high level canal. Before Tungabhadra dam, the canals were fed by the diversion weirs located at Koragallu, Vallabhi puram, Ramanagadda and Kuruvagadda. (13) The Koragallu and Vallabhi puram weirs acted as a pair in series connecting a rocky island in the centre of the river to either bank. The whole width of the river was spanned. The Ramanagadda and Kuruvagadda worked in parallel taking advantage of the river bifurcation at Anaveri. The Ramanagadda weir was located at the point where the river flow divided around the island and Kuruvagadda. It forced water between the island and the right bank of the river. The Kurvagadda anicut located down stream of the Ramanagadda weir had completely dammed the right bank of the river.

2.4. The weir at Vallabhi Puram supplied by the Basavanna canal. The anicut was 300 m long and straight in plan and was constructed of loose stones. The Koragallu weir fed a series of canals and the anicut was of loose stone construction done during the reign of Krishna Devaraya. A new one in year 1848 replaced the Vallabhi Puram anicut by Madras Irrigation Company and was further raised between 1927 and 1928. The Ramanagadda and Kuruvagadda anicuts supplied the Raya canal. The Ramanagadda anicut took the form of a low deflecting wall of loose masonry held together by stone clamps and pegs. The weir took advantage of the uneven nature of the riverbed integrating rocks and boulders which lay in the stream (8).

2.5. The Kuruvagadda anicut 4.8 km downstream joined the right bank of the river to the Kuruvagadda Island near village Hoskote (13). It was 22 m long and concave towards the flow in plan and constructed in rough stone masonry without martar. The

Gowripuram Vanka, a local stream, collected the surface run off from the south west side of the Sandur hills and discharged into the river, part of the flow was fed into the Raya and Basavanna canals (13). The Raya canal has remained essentially to its original form and it has three functions (13).

1. To irrigate a large portion of the land between Hospet and Kamlapuram village
2. Supply Kamalapuram tank with perennial supply. 13(A, B, C, D)
3. And also supply Kalaghatta canals

The Basavanna canal has been subjected to a number of changes after originally constructed in the year 1521. During the 19th century a number of modifications were done to improve its efficiency. As mentioned earlier the Raya canal was built during the reign of Krishna Devaraya (1509-1530). There is also evidence that this canal was originally built during the reign of Bukka II (1399-1406). The British engineers between 1856 and 1873 to improve the efficiency modified both the Raya and Basavanna canals. They were again further modified during the construction of TB dam.

2.6. The Hiriya canal irrigates an extensive area of land from Hampi to Bukka Sagara near Kampli (14). The Canal is fed by an arrangement of six weirs known as Hiriya and Turtha anicuts which block the flow of Tungabhadra between a low fertile island and the river's right bank. The supply of the Hiriya canal is boosted at two points firstly by the Kalaghatta canal, which passes the water from Raya Kaluve into the Hiriya canal. (15) Secondly the outlets and waste weirs of the Kamala puram tank discharge water into a single canal that connects the Hiriya canal. The Hiriya anicuts, which were originally constructed in the medieval period, have all been rebuilt in the modern times. Five small and one large diversion weirs divert water from the river into a single channel at about 2.5 km from Hampi. The weirs joining together out crops and shoals block the whole width of the river channel (16). In the post monsoon period the entire flow of the river is diverted making the river almost dry (17). The Anegundi Anicut and canal (14, 15) 19kms long commanding a large area and ends in another canal which takes off from the river at Suryanagundi.

2.7. These weirs may be divided into two groups, a series of five and the other larger single one. (17) The five are relatively small and are irregular in plan connecting with convenient obstructions protruding from the bed of the river. The sixth and the southern most is much larger and regular in plan (18). The five small anciuts take the form of low walls constructed from neatly dressed blocks of granite laid in regular courses and bonded with cement. Predominantly the weirs are provided with vertical faces on the upstream and downstream. However isolated sections have vertical upstream face and a gently curved down stream face. The remains of the original weirs are close to the new dam just downstream. These consist of rectangular slabs laid in regular courses with their short faces against the flow. Small holes are drilled at irregular intervals on top surface of each slab. (19) It is conceivable that iron clamps set in lead were used to bond them together instead of cement. The sixth and the southern most anciut is separated from the rest five by a rocky island.

2.8. The design of the canal uses the terrain with natural features, in particular, the out crops and boulders act as elements of the design, reducing constructional costs. The canal is not so much imposed on the landscape as determined by it using geographical peculiarities to their best advantage. The canal winds gently around and between natural boulders using them to impede flow or cause turbulence when a conversion of potential to kinetic energy is required. The design of the canal may be considered organic and functional utilizing natural resources with a minimum of superfluous labor and expense. The longevity of the irrigation systems is remarkable. The achievement of its builders is creating a durable and effective means of irrigating extensive agricultural tanks away from the river is measured by its continued use up to the present day. There are evidences that surface tanks with stone revetting existed during the first millennium BC in the pre Vijaynagar period

3. IRRIGATION DEVELOPMENT IN OLD MYSORE STATE

3.1. Agricultural production depends to a great extent on the development of irrigation. The tanks are the oldest in the irrigational system. In ancient days the cultivators constructed small tanks across streams to impound sufficient water for tier forming needs. They were any number of tanks of this description. The Moti Talab in Mandya district was one of the big tanks supplying water for wet cultivation. Major sankey one of the earliest engineers who worked in the mysore state addressed himself to the task of repairing tanks. In memorable words he has said "to such an extent as the principle of storage been followed, that t would now require some ingenuity to discover a site for a new tank. While restorations are, of course, feasible any new work of this description would within the area be almost certainly found to cut off the supply of another, lower down and to interfere in fact with vested interests". Though there are many isolated tanks in various regions the vast majority oft hem are on a connected system of streams and their feeders which are abundant in the tale lands of old Mysore.

3.2. There are many epigraphical records that indicate that irrigation had been practiced from Historical times in the erstwhile Mysore state, which is now merged in Karnataka. The inscriptions of the Ganga, Cholas, Hoysalas and the Vijayanagara and Mysore rulers not only speak of tanks, canals, sluices and other means helpful to facilitate irrigation but also mention about the steps taken for the conservation of such means of irrigation like repair of embankment , or desiliting of tanks etc.. The tradition of setting some piece of land in every village as *bittuvatta* also appears to be very old. Persons enjoying such land were charged with the responsibility of the upkeep of the village's irrigation facility. Copper plate inscriptions of the sixth century AD described Punnadu (present Heggaddevana kote region) as resplendent with Cauvery and Kabini river waters irrigating fertile fields with crops indicating a flourishing state of agriculture.

3.3. Irrigation was properly taken care of right from the Ganga Dynastic rulers' times in the 9th century along with the bittuvatta system for their proper upkeep. Excavation of tanks in Ganga times is referred in many records. The Gattavadi record mentions that there was a tank called Gallakkere prior to 904 A.D. excavated by a queen, and Shivayya a Brahmin scholar who caused the construction of the tank which was huge comparable to an ocean. At a place called Puttagoudanahalli, a local woman constructed a tank for irrigation and gave some land for bittuvatta. In about the 9th century, a Ganga officer provided a new sluice. Likewise there are numerous references to construction of tanks and canals from age old times. A type of Persian wheel called *Araghatta* was in use in the 13th century

3.4. Extension of irrigation facility by royal efforts continued not only in the days of Vijayanagara, but also under the Mysore rulers as well. Madhava Manthri, a Vijayanagara officer at Talakad, raised the famous Madhava Manthri Katte (20 & 21) (Weir) between the places Hemmige and Muduktore across the Cauvery in about the year 1341 and a record of the year 1638 speaks of it as (*Madarasa Vodeyara Katte Kaluve*). There is an old anicut at Dhanagere across Cauvery in Kollegal taluk and another at Ganiganur across Suvarnavathi River. The Mysore rulers also continued to take proper care of irrigation. The creation of canal by directing the flow of the river Lakshmanathirtha a tributary of Cauvery is mentioned in a record of the year 1669 and the tank is named Kantheerav Samudra. Tipu Sultan the famous Muslim ruler of Mysore State in those times raised a bund of 70 feet high in Anandur in Mysore taluk. In the days of Dewan Purniah a Popular Minister during the rule of Krishnaraja Wadeyar III, the sagarkatte dam was raised across Lakshmanathirtha. At Devanur, construction of a tank, Devarakatte is spoken of during 19th century. Chunchankatte has an old dam ascribed to one Chuncha. The Mysore rulers of those times, Kanthirava and Chikkadeva Raja had undertaken a number of irrigation works.

3.5. During the regency of Dewan Purnaiya, a generous sum \was spent on irrigation works. This expenditure was, to a certain extent incurred on the repairs of old tanks and canals, the majority of which had fallen into disuse during the reigns of Hyder-Ali and Tipu Sultan. During the period when the British commission was in power in Mysore, a large amount was spent on irrigation works. Most of the tanks were improved and many reconstructed from the disuse condition into which they had fallen. After the formation of the public works departments in 1856 the expenditure of the irrigation went up. Special attention was directed to irrigation between the years 1872 and 1878 because separate irrigation branch of the public works department was constituted.

4. TANK POLICY

4.1. The restoration of disused tanks had come to a definite state of advancement by the time the sate was handed back to the Mysore Maharaja in 1881. In 1856 the government of Mysore decided to hand over all the minor tanks yielding a revenue not exceeding Rs 300 to the cultivators for doing earth work themselves and the government only paying for masonry works where needed. All the other tanks were called major tanks. The restoration of these major tanks was the direct responsibility of the government and the cultivators contributed a moiety for their betterment. This scheme was tentatively introduced in one tank of each district and after a trial, was extended to all the other areas. A tank inspector was appointed in each taluk to assist the Amildar the revenue official in charge of the taluk and a trained sub-overseer was posted in each district to help the tank inspectors in technical matters. Under the rules issued in 1904, the cultivators were required to contribute 1/3rd of the total cost of restoration including earthwork, the other 2/3rd met out of public funds. In selecting tanks for restoration, preference was given to those tanks where the cultivators came forward with their contribution.

4.2. With a view to making the minor tanks restoration scheme a success, it was decided that larger and more liberal Government grants be made available for the improvement of such tanks. In regard to the maintenance, the cultivators were responsible for doing the earthwork to keep the bunds in strong healthy conditions. The repair to stone revetment and masonry were done by the government. In order to provide for the obligation of cultivators in regard to maintenance of major tanks and restoration, the government of Mysore in 1911 passed a regulation called the tank Panchayat regulations. The panchayats constituted under this regulation had absolute control over the tanks as also the power to administer the funds earmarked for the restoration, repair and maintenance. 1916 the minor tanks restoration regulation XIII of 1916 was passed, providing for the recovery of the cultivators share of cost of restoration compulsorily. Later measures fixed the cultivators contribution at $1/4^{th}$ of the actual cost of the restoration among the many tanks the Thonnur tank called also the Moti Talab is an old tank with historical association functioning effectively even to this day. The bund of this tank is said to have been constructed in the 12^{th} century by Saint Shri Ramanuja charya who named it as Tirumla sagar. Later Nasir Jung son of the Subedar of the Deccan gave it the name of the Moti Talab

5. RIVER DIVERSION WORKS FOR IRRIGATION

5.1. The Mandya district of this state is blessed by nature with perennial rivers, the waters of which are used for raising wet crops. Even in the old days anicuts were constructed across these rivers and the canal waters were let into the fields for growing paddy, sugarcanes and other water fed crops. The rivers in the districts, which have been put to irrigation use, are the Cauvery, Hemavathi, Shimsha and other small rivers and streams.

5.2. There are six old anicuts named Mandagere, Hemagiri and Thaggally anicuts and the later are the Bolenehalli, Uyyanahalli and Dummasandara anicuts. The Mandagere old anicut is 666 ft in length with two channels 37 miles long on the right side and 21 miles long on the left side. The Hemagiri anicut is also an old one across Hemavathi constructed is size stone masonry in surki mortar and is 1,360 feet in length. The left bank canal is 23 miles long. The Thaggally anicut across Shimsha River is 825 feet in length having a right bank canal of 12 miles and the left bank canal of 23 miles. The Bolenehalli anicut across Lokpavani River is 132 feet long is meant to feed the Madarahalli tank. The Uyyanahalli anicut is 370 feet long with a channel of 3 miles length. The Dummasandara aicut is 400 feet long with a right bank canal of 4 miles.

6. ANICUTS ACROSS CAUVERY RIVER

6.1. Several anciuts have been constructed across the Cauvery and its main tributaries for supplying water for irrigated lands. These anicuts and canals are very old and are functioning even to this day. A table showing the various anicuts across the Cauvery and the Hemavathi rivers along with the area irrigated is given below

6.2. The lower channels in the Cauvery valley given in the table below

Slno	Name of the anicut		Area irrigated in acres
1	Chikkadevarayasagar		14,245
2	Devaraya		2,022
3	Virajanadi		7,420
4	Bangaradoddi		762
5	MaddurAnicut		1,493
6	Kemmanu		958
7	Vaidyanathpur		249
8	Bairan		280
9	Chamanahalli		607
10	Mandagere		3,043
11	Hemagiri		1,381
12	Akkihebbal		380
13	Kalhalli	Since submerged in	1,216
14	Kannamabdi	Krishnarajasagar reservoir	1,156

Slno	Channel	Length	Extent of irrigation in acres
1	Virajanadi channel	42 miles	10,094 acres
2	Devaraya channel	23 miles	2,409 acres
3	Chikkadevaraya channel	72 miles	Not available
4	Bangaradoddi channel	5 miles	920 acres
5	Right bank low-level channel	19 ½ miles	3,420 acres
6	Left bank low-level channel	13 miles	1,430 acres

6.3. Even prior to the construction of Krishna Raja Sagara dam these channels were existing and were supplying water for irrigation. Close to the village Sitapur in Sri Rang Patna, taluk is the Madad katte dam, a low straggling structure of rough stone 2328 feet in length and averaging 45 feet in width. From this small dam the Chikkadevaraya channel is led off. This channel runs to a total length of 72 miles in both Mandya and Mysore districts. In its course the channels crosses the Anchehalla and Mosalehalla streams and also the Lokapavni River. Both the dam and the channel were constructed at the time of Shri Chikka Devaraya Wodeyar celebrated ruler of Mysore. The Balamuri anicut on the Cauvery river is situated one mile from Belagola giving rise to the Virajanadi channel on its right bank. The channel runs to a length of 38 miles in the Mysore district. The Bangaradoddi anicut is constructed across the Paschimavahini branch of the Cauvery River. The channel drawn form this anicut after crossing the little

Paschimavahini Island is led over to the Sri Rangapattana Island by means of an aqueduct (22, 23 & 24). It then divides itself into three branches, one entering the Sri Rangapattana fort by means of an under ground duct, the second terminating at the Darya Daulat garden and the third after traversing the islands ends near the Gumbaz.

6.4. Irrigation as practiced within Mysore state at that time was either from tanks a vast number of which existed all over the area or from channels from the rivers which were in the Cauvery valley. The tanks played an important part in producing rice and garden crops but the irrigation from this source was not always dependable. In 1876-77 a year of extreme drought the country suffered much for want of food and about $1/5^{th}$ of the population of the old Mysore state is said to have died from the effects of the disastrous famine. The irrigation from the old Cauvery channel was more secure, but its command area was small. Water from these channels was usually available only for the first crop and the irrigation of the perennial crops suffered from serious disabilities. Water supply in summer was precarious and crops like sugarcane and mulberry could not be extensively cultivated. It was therefore proposed to provide water for irrigation through out the year for perennial crops. In pursuance of this proposal it was thought best and feasible to impound the waters of the Cauvery on a large scale by recourse to modern aspects of hydraulic engineering. This led ultimately to the construction of the Krishna Raja Sagar dam in the year 1911-1930 under the guidance of Sir M. Vishveshwaraya the world famous engineer of yester years. As a precursor to this large dam is the construction of the Marikanive Dam across Vedavathi River in the drought prone Chitraduraga District.

7. IMPORTANT HISTORICAL STRUCTURES IN THE COUNTRY

7.1. In Madhya Pradesh, near Gwalior city there is a dam named Tigra Dam (25) which was constructed in the early part of the last century. This dam is presently serving the water supply needs of the city although primarily it was constructed for irrigation purposes. The transformation was due to the fact that the population of the city increased in the last one hundred years that the storage had to provide for drinking water supply needs of the growing city. Gradually the irrigation had to be cut down to a negligible extent. Drinking supply need has always an overriding priority over irrigation. The importance of this dam lies in the fact that for the first time (perhaps in the world) it was recognized that there is such a phenomenon as uplift force that needs to be taken into account in the design of the modern dams for stability.

7.2. The then Gwalior state which is now merged in Madhya Pradesh constructed the masonry dam during the years 1913-1917 over what appeared to be sound rocky foundation across the river Sank about 18kms from the Gwalior city. The dam was hundred feet high over the deepest river bed. However in the very first year of completion in the year 1917 when the dam was full, all of a sudden it breached for a length of 800 feet in the deeper river portion emptying the dam almost with a burst. The bursting force of the water was so much that entire sections of the dam in blocks along with the foundation strata was carried down stream and large blocks of masonry moved kilometers downstream. (26) Fortunately as the breach occurred during day time there were minimum loss of lives and property although some villages downstream were washed down.

7.3. The engineers at that time were at a loss to know the reason why the dam breached although the quality of construction in masonry was very good and the foundations were in massive rock. Advice was sought by the Gwalior state from outside abroad both from US and UK experts. It was only after 12 years of investigation that it was realized that the foundation strata was of sand stone formations with horizontal seams and crevices between massive layers of sand stone formation at considerable depths in the deepest portions. With the storage full of nearly 100 feet deep the hydrostatic pressure found way in these seams and crevices acting vertically upwards below the foundations of the dam reducing the gravity force of the dam holding down to the foundations. The dams were designed in those days as gravity structures which stood well on rock foundations like granite, basalt and other igneous formations which do not have the horizontal stratifications. Perhaps for the first time a masonry dam of that height was founded on stratified sand stone formation with seams and the uplift pressure in these seams at Tigra Dam caused the failure and ultimate bursting of the dam. This was realized by the expert engineers who had to make modifications in the design and construction to reduce this uplift pressure.

7.4. In the deeper portion of the valley upstream of the breach portion a deep trench was excavated and filled with impervious clay and a clay blanket was laid for a thickness of 3 feet tying the trench for a distance of nearly 2kms upstream. A clay blanket and the trench filled with clay was covered with a layer of quarried stones for protection. Later the breach portion of the dam was reconstructed with the same section on the rocky foundation for the entire length of 800 feet. The clay blanket and the trench reduced the uplift pressure drastically providing stability to the new dam sections. The dam is now standing since 1929 when it was reconstructed and serving the needs of the city even to this day.

7.5. Since this experience in the dam design technology the uplift force has been taken into account and modern dams are designed accordingly to provide stability. To reduce the uplift force the modern dams are now provided with foundation drainage galleries in which curtain grouting is done with cement to seal of joints seams and cervices after washing the drilled holes to sufficient depth removing any clay and soft materials. Usually the curtain grouting is done to a depth of half the head of the water in the upstream and is accomplished with a line of drilled holes at close intervals. As a further precaution in the drainage gallery, drainage holes are drilled at the downstream face of the gallery to release uplift pressures further. Usually the curtain grouting and drainage holes re drilled after a part height of the dam is constructed. This has become a modern practice after learning a lesson from the failure of the Tigra dam and hence its importance.

7.6. Close to Bhopal the capital of Madhya Pradesh, is a place called Bhojpur on the banks of the Betwa River in its head reaches. During the reign of Raja Bhoj the then ruler of a small kingdom which is now merged in Madhya Pradesh, a crude earth rock filled dam was constructed across the Betwa river in the 12th century. The dam abuts a rocky hillock where a cut was made to provide for the flow of excess floods of the river without damaging the rock fill dam in the gorge of the river. Perhaps it was here for the first time that the engineers of those days had understood flood hydrology and accordingly provided for the surplusing arrangement to provide for the safety of the dam when the river is in floods. This could have been a lesson for the engineers later to understand flood hydrology and accordingly provide for such surplusing works as waste weirs, spill ways etc. At present at Bhojpur only the breach portion of the dam is standing as a witness even to this day. It is reported that the breach was not due to any natural cause or flooding but was done intentionally by a subsequent Nawab Ruler to make use of the silted lake bed to grow wheat in a large scale to ward off a severe famine affecting his subjects.

8. CONCLUSION.

8.1. The historical account in brief picking out some significant aspects in history of irrigation development in country is made out in this paper with a view that some important lessons can be drawn from this account. The traditional and age old techniques of the past could be integrated with the modern technology so that a more effective technology could be developed and at the same time comprehensible enough for adoption retaining some of the good aspects of the traditional practices. In this paper it has not been possible to incorporate all the geographical location with descriptions for getting a back ground of the many irrigational structures. However the intention was to give a feel of the engineering techniques that were used in the past. An important feature of the tank system is the interconnection of a group of tanks in the same valley as chain system of tanks the surplus of one is the upper seeding, the lower to conserve as much water as possible for irrigation and domestic supply. A second feature is the construction of a cistern downstream of the bund at the head of the sluice so that washing and bathing is done outside the water body of the main tank to prevent pollution as illustrated in the pictures of Kamala Puram tank (13 A, B, C, and D). To the extent some illustrations were easily available have been incorporated to make a sense of what has been described in that paper.

REFERENCES:

1. The irrigation and water supply systems of Vijayanagara by Dominic J, Davison-Jenkins, published by the American Institute of Indian Studies year 1997.
2. Mysore District Gazetteer of Karnataka
3. Mandya District Gazetteer of Mysore State

LIST OF ILLUSTRATIONS